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Ecological and Floristic studies on the *Myristica* swamps and its Adjoining Forests of Dakshina Kannada region of The Western Ghats

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By

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INTRODUCTION

The Western Ghats is one of the 35 biodiversity hot spots (Zachos and Habel 2011) and one of the 12 mega diversity centers in the world (Chand *et al.*1992 & Varghese & Menon 1999,). The Western Ghats of India and Sri Lanka biodiversity hotspot is often regarded as one unit because of shared bio geographical history (Gunawardane *et al.* 2007). It is a chain of mountain ranges stretching North – South along the western peninsular India for about 1600 Km covering 1.0045 lakh / sq Km. Western Ghats are known as 'Sahyadri' mountain ranges (Prajapathi 2010). This stretch is discontinuous for about, 32 Km in Palghat and it is called Palghat gap (Pascal 1988). The Western Ghats is located geographically between 08° 19' 18" – 21° 16 '24" N and 72 °56' 24 "– 78° 19' 40" E covering an area of 1, 64,280 Km^2 which is 5 % of the total geographical area of India.

The Western Ghats also include many fresh water swamps. These are the wetland ecosystems that arise when inundation by water produces soil dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate the flooding (Keddy 2000).

In India, fresh water swamps are reported from the Siwalik and Doon valley and the Brahmaputra valley (Rao 1994).

In India, *Myristica* swamp for the first time was reported by Krishna moorthy (1960) from Kulathupuzha region of Western Ghats of Kerala.

After the discovery of *Myristica* swamps in 1960 upto four decades none ever referred to such a unique habitat nor was anything notable added upto four decades thereafter till

Chandran (1997) reported the *Myristica* swamps in Uttara Kannada District have been converted into rice fields and gardens of Aeracanut.

Subsequently in Uttara Kannada district of Karnataka these swamps were studied by Chandran *et al.* (2005) and revealed the presence of 51 patches of swamps covering an area of 98175 m^2.

Swamp forests were also reported in the Satari region in Goa (Santhakumaran *et. al* 1995). Nair *et.al* (2007) reported 60 individual swamp patches in Southern Kerala constituting an area of 1.5 km^2 which hardly make up 0.004% of the total land area of Kerala and 0.014% of the total forest area of the state.

Myristica swamps are any patch of forest in the perennial swampy regions in the evergreen forests of the Western Ghats dominated either by *Gymnacranthera canarica* (King.) Warb. or *Myristica fatua* Houtt. var. *magnifica* (Bedd.) Sinclair. or both. These two species occur from the sea level upto 1000m altitudes. These swamp species occur in association with other usually evergreen trees having varied degree of flood tolerance. Almost all *Myristica* swamps are situated in small streams or stream beginning areas, trees being distributed on both sides of these streams. (Roby *et. al* 2007). Champion and Seth (1968) classified this type of vegetation as Tropical fresh water swamp forests (4C/FSI).

Special kinds of adaptations like aerial adventitious roots called 'stilt roots' / 'knee roots' that springs out from the main trunk providing additional support to the swamp trees in the soil. Such roots might become woody and flattened with age becoming flying buttress as in *Myristica* sp., *Gymnocranthera* sp. *Elaeocarpus* sp., *Holigarna* sp., *Madhuca nerifolia, Pandanus* sp. etc. (Chandran and Mesta 2001). Apart from these, *Myristica* swamp is the prime habitat for the critically endangered tree *Syzygium travancoricum* Gamble. (Roby and Nair 2007).

These swamps need special conditions such as flat bottomed, deep soil in the adjoining hills with rock layer, slow seepage of water to be stored above the rock layer, slow seepage of water from the hills into valley throughout the year, heavy annual rainfall upto 3000 mm and temperature ranging from 20 -30 º C. (Chandran *et. al* 1999; Varghese *et.al* 1999 & Nair *et.al* 2007) Hence these swamps are highly restricted in distribution and occurrence and are considered as a critically endangered ecosystem (Chandran *et al.* 2005; Roby *et al.* 2014). Moreover, these are less understood in terms of their structure and floristics.

Therefore, studies are carried out with the following **objectives**:

1) Mapping of *Myristica* swamp forests in Dakshina Kannada district using remote sensing and estimation of the area of swamp through remote sensing.
2) Detailed Phytodiversity studies of the *Myristica* swamp forest and its adjoining forests
3) Structural studies of the *Myristica* swamp forests and its adjoining forests with regeneration status of the swamp species and soil studies
4) Germination studies of selected swamp species

MATERIALS AND METHODS

Location of Swamps

- The occurrence and locating of *Myristica* swamps in a region was done by interviewing the local people.
- Using this as the ground truth data, further, remote sensing data was used to locate newer areas of swamps

1. Mapping of *Myristica* swamp forests in Dakshina Kannada.

The already identified areas will be used as training sets to evolve a supervised classification of the area for swamp vegetation. Hand held Global Positioning System 'Garmin – etrex - vista HCX' (GPS) is used for recording the latitude – longitude data in the field.

Data used for Remote Sensing

Resource sat is the Indian Remote Sensing (IRS) satellite launched by Indian Space Research Organization (ISRO). The geo rectified Resource sat satellite image was obtained from National Remote Sensing Center (NRSC), Hyderabad, Dept. of Space, Govt. of India.

Methodology of processing Resources sat 2 Satellite Image

1. The image was processed in Earth Resource Data Analysis System (ERDAS) imagine software 9.1. The image was processed in Remote Sensing Laboratory of National Centre for Coastal Research (NCCR) Pallikaranai, Chennai. The satellite images were acquired from the National Remote Sensing Center (NRSC), Hyderabad.
2. The satellite image was imported in to the ERDAS Imagine environment. Geometric correction has been applied on image using Geographic Lat/Long. The re projected function modifies the projection of a raster dataset, mosaic dataset, or raster item in a mosaic dataset. It can also resample the data to a new cell size and define an origin. The image was later displayed as virtual stack to get the False Colour Composite (FCC) image. FCC image enables one to identify the reflectance by vegetation more clearly than in true colour composite image. The sample locations were identified using the coordinates collected during the field sample collections. The location map was created using the map composer.
3. **Maximum Likelihood classification:**

   Different training sets were assigned to one of the land cover classes such as vegetation, open land, dense forest, water etc. The Maximum Likelihood Classification (MLC) algorithm was the chosen method for supervised classification. Multiple training sites were assigned for each class for better classification. Spectral signatures of like land cover type were then merged so that each area would only have one spectral signature for each land cover class. Maximum Likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood).

2. Phytodiversity studies of the *Myristica* swamp forest and its adjoining forests

The plant specimens of all the species were collected and herbarium was prepared. Identification was done using relevant floras like Flora of the Presidency of Madras (Gamble 1915-1936), Flora of Karnataka (Saldhana, 1996), Field key for the identification of the tree species of Western Ghats (Ramesh & Pascal, 1987) and

Flora of South Kanara (Bhat 2014). The endemic plants were listed according to Ahmedullah & Nayar (1987) and Singh *et al.* (2015).

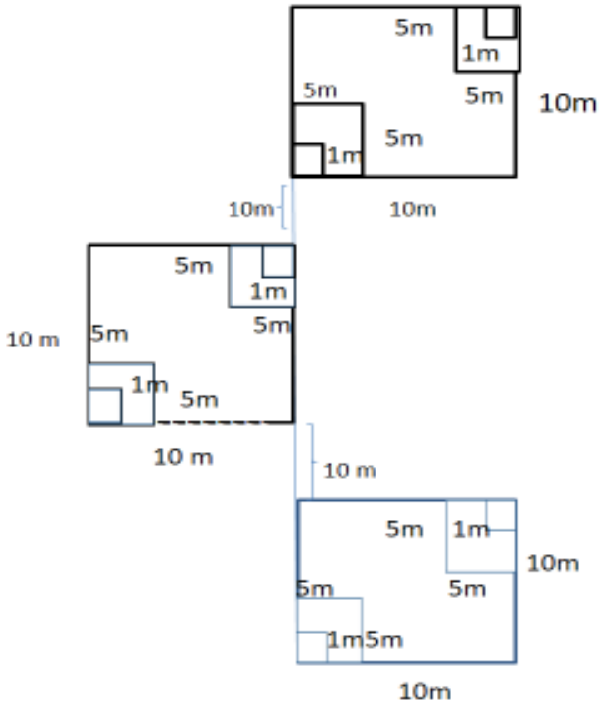
3. Structural studies of the *Myristica* swamp forests and its adjoining forests

Sampling Methods

Line transects with quadrats of 10 X 10 m were used for sampling. Quadrats were laid on either side of the line transect alternately. Interval between quadrat was 10 m. (Fig.1). The length of the transact varied from swamp to swamp depending upon the size of the swamp. In smaller swamps, sampling was done by laying qudrats of the size 10 X 10 m without leaving any interval gap in order to cover the full extent of the swamp. In larger swamps, one hectare plots were used for sampling. Such plots were further divided into 10X10 m quadrats

Line transects, sampling plots and quadrats were demarcated using Nylon ropes. GBH (Girth at Breast Height) were measured for all the plants (Trees, shrubs and lianas) having a girth of ≥ 10 cm. Girth measurement was taken at a height of 1.3m from the ground surface. For multi - stemmed trees bole girth was measured separately and trees having buttresses, measurements were made just above the buttresses. Plants with ≤ 10 cm GBH were counted and recorded. Fig.1

Quadrat lay out along the line transects.



Data Analysis

The data were quantitatively analyzed for basal area, relative density, relative frequency and relative dominance (Phillips 1959).The Importance Value Index (IVI) for the tree species was determined as the sum of the relative density, relative dominance, relative frequency (Cottam & Curtis,1956).

$$\text{Basal Area} = \frac{(GBH)2}{4\pi}$$

$$\text{Density} = \frac{\text{Total No.of Individuals of the species in all the sampling units}}{\text{Total No.of sampling units studied}}$$

$$\text{Dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}}$$

$$\text{Frequency} = \frac{\text{No.of sampling units in which species occured}}{\text{Total No.of sampling units studied}}$$

$$\text{Relative Density (rD)} = \frac{\text{Total No.of Individuals of the species in all the sampling units}}{\text{Total No.of sampling units studied}} \times 100$$

$$\text{Relative Dominance (rd)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

$$\text{Relative Frequency (Rf)} = \frac{\text{No.of sampling units in which species occured}}{\text{Total No.of sampling units studied}} \times 100$$

Importance Value Index (IVI) = Relative Density (rD) + Relative Dominance (rd) + Relative frequency (Rf)

Family Importance Value

It is the sum of the importance value index of all the species of the family.

Percentage of Evergreeness

$$\% \text{ Evergreeness} = \frac{\text{No.of evergreen trees}}{\text{Total No.of trees}} \times 100$$

Percentage of Endemism

$$\% \text{ of Endemism} = \frac{\text{No.of Endemic trees}}{\text{Total No.of trees}} \times 100$$

Diversity Indices

1. Simpsons' Diversity Index, $D = 1 - \sum (ni / N)^2$

   Where ni = total number of individuals of the species

   N= total number of individuals in the plot

2. Shanon Wieners diversity $H' = \Sigma Pi (\ln Pi)$

   Pi = the proportion of the species

3. Equitability Index = $\log_2 S$

   $$E = \frac{H'}{H \max}$$

4. N/S Ratio

   It is the ratio indicating the number of individuals of each species to total number of species

Statistical Analysis

Data was subjected to statistical analysis using R - Software

Soil Analysis

Sampling Methods

Soil samples were collected randomly from the studied area. The soil samples were collected using soil corer from the surface and depths of 0-10cm, 10 – 20 cm and 20 – 30 cms. The soil samples from the same study site and layer were mixed thoroughly, air dried and passed through a 2mm mesh sieve to remove the debris, stone and root particles etc.

The Composite sample was used for detailed soil analysis.

Soil Analysis was carried out for the following parameters:

i) pH - using digital pH meter.

ii) Total Nitrogen by Kjeldahl Method (1883)

iii) Available phosphorus by Bray *et. al* (1945) Method

iv) Availabilty of Potassium by flame photometer

v) Organic carbon by Walkley and Black Method (1934)

4. Germination studies of selected swamp species

Germination studies were carried out in *Lophopetalum wightiaum* Arn. and *Gymnacranthera canarica* (King.) Warb.

1. Collection and Processing of Seeds

Seeds were collected from the *Myristica* Swamp forest of Charmady and Belthangady Forest ranges of Belthangady taluk - Dakshina Kannada District of Karnataka in the month of April 2013 and August 2013.

Immediately after collection, healthy seeds without any apparent physical damage were selected for the experiments. Germination of *Lophopetalum wightianum* seeds was carried out in 6 replicates containing 16 seeds in each sand bed. To check the seed viability seeds were sown on 1st day, 5th, 10th, 20th and on 30th day after collection.

For the seeds of *Gymnacranthera canarica, a*fter collection, the seed aril was removed. The seeds were washed in water, seed samples without any insect infestation and physical damage were selected for the experiments. To check the viability and germination behaviour, initially seeds were sown twice with 10 days interval. Later they were sown at an interval of 5 days up to 100 days in 2 replicates. 60 seeds were taken in each experiment. Remaining seeds were used to test moisture content and for viability test.

Parameters studied

Germination Tests, Moisture content, Desiccation study, seed viability, Cumulative daily total number of seeds germinated, Germination Energy, Germination Speed Germination Percentage and Vigour Index were studied.

Germination test

Germination percentage is determined by using sand bed method (ISTA 1985). The seeds were pressed into the surface of sand with a distance of 4 cm on the sand bed. (ISTA 1991). Seeds were watered daily. Germination was scored on the emergence of the radical (2cm in length) and results are expressed as percentage of seeds germinated.

Moisture content

Moisture content (MC) of the seeds was determined following low constant oven drying method (ISTA 1991).Randomly selected seeds were cut into pieces of definite quantity (5g). Then dried at 103º C for 17 hours in hot air oven. This experiment was done in triplicate. Seed moisture content was calculated on a fresh mass basis using the following formula.

$$\text{Moisture percentage} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where, M_1 - is the weight of petriplates; M_2 - is the weight of petriplates with seeds before drying; M_3 - is the weight of petriplates with seeds after drying.

Desiccation study

After procuring the seeds, clean and pure seeds were selected for the study. Seeds were desiccated up to 10-12 % moisture content (Hong and Ellis, 1996.) Desiccation was performed by mixing equal amounts of self indicating silica gel in glass desiccators. The seeds were mixed twice a day to get proper aeration. (IPGRI, 2000 and Varghese *et al*. 2002). Since the seeds of *Lophopetalum* have a very short life span desiccation study is carried out only in *Gymnacranthera* seeds.

Seed Viability

Seed viability was evaluated by taking seeds randomly from the seed lot, treating dissected seed with embryo with 1% 2, 3, 5 - triphenyl tetrazolium chloride solution (TZ) for 17 hours (ISTA, 1999).

Cumulative daily total number of germination of seeds (CDTG)

Cumulative daily total number of germination of seeds (CDTG) was recorded on a daily basis. This was used for calculating the number of seeds germinated per day.

Germination Speed (GS)

Germination speed was estimated according to the method prescribed by Maguire, (1962) using the formula

$$\text{Germination Speed} = \frac{G_1}{T_1} + \frac{G_2}{T_2} + \frac{G_3}{T_3} \ldots\ldots\ldots \frac{Gn}{Tn}$$

Where G_1 - Number of seeds germinated on first day

G_2 - Number of seeds germinated on second day

G_3 - Number of seeds germinated on third day

T_1 - Day one; T_2 - Day two; T_3 - Day three

Germination Energy (G.E.)

It is the number of days required to attain 50% of germination. (Allen 1958)

Germination percent

It is the ratio to number of seeds germinated to the number of seeds kept for germination

$$\text{Germination per cent (\%)} = \frac{No.of\ seeds\ germinated}{No.of\ seeds\ kept\ for\ \ gerination} \times 100$$

Statistical Analysis

Data was subjected to analysis of variance (ANOVA) and Pearson's correlation in SPSS Version 17.0 and in Sigma Plot version 11.0

RESULTS

The supervised classification was carried out using FCC image (band 3, band 2, band 1). About nine different classes were defined those existed in the present study The total area of each class was calculated as given below.

Total area of each class = count of pixel * cellsize^2

The classified image showed 278.87 Km^2 of *Myristica* swamps.

Table 1: Area calculation of each class in supervised classification.

Sl. No	**No. of Pixels**	**Classes**	**Area (KM^2)**
1	3556515	Dense Forest	1964.09
2	1789650	Dry/Open land	988.33
3	64387	Hilltop/Built up area	35.56
4	504972	*Myristica* swamps	278.87
5	82467	Open land	45.54
6	446	Road/Rail	0.25
7	3561	Sand	1.97
8	962772	Vegetation	531.69
9	94769	Water	52.34
Total	7059539		3898.63

1. **Detailed Phytodiversity studies of the *Myristica* swamp forest and its adjoining forests**

Floristic study of *Myristica* swamps resulted in the documentation of 150 species belonging to 114 genera and 51 families (GBH ≥ 10 cm). Of this, 40 species are endemic to the Western Ghats and three species are critically endangered *Blepharistemma serratum* (Dennst.) Suresh is endemic and monotypic.

Plants ≤ 10 cm GBH harbours 46 species belonging to 41 genera and 28 families of this 7 Species are endemic to Western Ghats, one species is endemic and critically endangered and one is endemic vulnerable. Five species of Pteridophytes were recorded of which *Schizaea digitata* (L.) Sw. is rare and endangered.

Adjoining Forests

Floristic studies on the adjoining forests of *Myristica* swamps resulted in the documentation of 155 species belonging to 122 genera and 70 families. Of these Plants ≤ 10 cm GBH harbours 35 species distributed 28 genera and 13 families

2. **Structural studies of the *Myristica* swamp forests and its adjoining forests**

For structural studies 55 swamps were taken. These are distributed in Sullia, Belthangady and Puttur taluk under the Belthangady, Venoor, Charmady, Dharmasthala , Panja, Kombar, Subramanya and Sullia forest ranges.

Structural studies on *Myristica* swamps

The entire 55 *Myristica* swamps have been grouped in to 4 groups depending upon the quadrats laid. .

Group I – Smaller swamps (less than 10 quadrats in the transacts) (n = 21)

Group II - Swamps with more than 10 quadrats and upto 30 quadrats (n = 20)

Group III– Larger swamps with more than 30 quadrats (n = 12)

Group IV– One hectare Plots (n= 2)

Important Value Index (IVI)

Important Value Index (IVI) reveals the dominant and co - dominant species in the ecosystem. Higher the important Value Index represents dominant species in the area. In all *Myristica* swamps *Gymnacranthera canarica* (King.) Warb. the exclusive component of swamp accounts for the highest IVI .The top 10 species in the decreasing order of their IVI for the different classified swamps and adjoining forests listed below.

Group I - Smaller Patches of *Myristica* swamps within line transacts below (10 quadrats)

Table2: Top 10 species in the decreasing order of their IVI of smaller Patches of *Myristica* swamps

Species List	IVI
Gymnacranthera canarica King.(Warb.)	89.6081
Holigarna ferrugenia Marchand	27.8761
Lophopetalum wightianum Arn.	24.6054
Vateria indica L.	21.4715
Hopea ponga (Dennst.) Mabb.	12.7235
Syzygium travancoricum Gamble	10.8677
Myristica malabarica Lam.	9.1988
Elaeocarpus tuberculatus Roxb.	9.1409
Holigarna arnottiana Hook.f.	7.8112
Aporosa cardiosperma (Gaertn.) Merr.	6.8469

21 smaller patches of *Myristica* swamps reveals the highest IVI of 89.6081 for *Gymnacranthera canarica* and *Holigarna ferrugenium* with an IVI of 27.8761.

i) Group II - *Myristica* swamps with in line transacts above 10 quadrats

Table 3: Top 10 species in the decreasing order of their IVI of *Myristica* swamps with in line transacts above 10 quadrats

Species List	IVI
Gymnacranthera canarica King.(Warb.)	94.6247
Lophopetalum wightianum Arn.	32.9742
Holigarna ferrugenia Marchand	22.3369
Mastixia arborea (Wight) C.B.Clarke	14.9758
Vateria indica L.	13.5119
Myristica malabarica Lam.	8.85907
Syzygium travancoricum Gamble	7.80337
Hopea parviflora Bedd.	7.48901
Hopea ponga (Dennst.) Mabb.	5.63227
Diospyros ebenum J.Koenig ex Retz.	5.54711

Larger area of swamp reveals the highest IVI *Gymnacranthera canarica* of 94.6247 and *Lophopetalum wightianum* with second dominant species of IVI 32.9742.

ii) Group III - Larger Swamps

Table 4: Top 10 species in the decreasing order of their IVI of Larger *Myristica* swamps

Species List	IVI
Gymnacranthera canarica King.(Warb.)	68.1676
Lophopetalum wightianum Arn.	37.8833
Holigarna ferrugenia Marchand	24.6536
Vateria indica L.	23.6823
Mastixia arborea (Wight) C.B.Clarke	13.2363
Myristica malabarica Lam.	13.0856
Syzygium travancoricum Gamble	7.97316
Hopeaponga(Dennst.) Mabb.	7.2753
Hydnocarpus pentandra (Buch- Ham) Oken	4.9086
Hopea parviflora Bedd.	4.5305

i .v) Group IV- One Hectare Plots

Two, one hectare plots were laid in the *Myristica* swamps of Belthangadi and Sullia Taluk. Sullia Taluk *Myristica* swamps. In Belthangadi Taluk (Panchar Male) swamp *Hopea ponga* is the dominant species with IVI 48.8957 and *Gymnacranthera canarica* is the second dominant species and in Sullia Taluk (Kalpata Male) swamp *Gymnacranthera canarica* is the dominant species 89.7183 and *Holigarna ferrugenium* is the second dominant species

Statistical Analysis of *Myristica* swamps

In this study 55 *Myristica* swamps have been located and studied for the structural parameters like basal area/ hectare, percentage of evergreeness, percentage of endemism and altitude. To understand the relationship and strength of association between these parameters Pearson's correlation and Principal component analysis have been carried out.

Pearson's Correlation Matrix

Inter correlation coefficients were computed among the four variables namely basal area, evergreeness, endemism and altitude. From the Pearson's correlation matrix it is observed that there is a relatively high correlation of 0.26 between endemism and evergreeness as compared to others. The correlation between altitude and basal area was negative and high i.e. -0.26. The correlation between endemism and altitude was 0.15 and the correlation between basal area and evergreeness is +0.09.

If the correlation between basal area and other characters are considered, it has high negative correlation with altitude and low correlation with evergreeness and endemism. Evergreenness has high correlation with endemism (0.26) and low correlation with altitude (-0.08). Endemism and altitude have a positive correlation of 0.1.

Principal component analysis

Principal Component Analysis of the data was carried out considering the basal area, evergreeness, endemism and altitude and it is observed that the first two principal components account for 64% of the cumulative variance. Eigen values for first two principal components were 1.15 and 1.12. The loadings of the first principal components account for mainly basal area and altitude with coefficients ¯ 0.635 and 0.694 respectively. The second component accounts for evergreeness and endemism with coefficients 0.726 and 0.661. Thus, the prime factors influencing the swamp vegetation were altitude and basal area in the first component and evergreeness and endemism in the second component. Since the correlation

among the four characters is low, principal component is not much useful in the interpretation of results.

Cluster Analysis

Based on the same parameters i.e. basal area, evergreeness, endemism and altitude clustering has been done. *Myristica* swamps have been grouped into five clusters. In these five clusters all the 55 *Myristica* swamps have been arranged viz. In cluster I has 8 swamps, with cluster II has 7 swamps, cluster III with 17 swamps, cluster IV has, 3 and cluster 5 has 20 swamps.

For the statistical clustering the mean values for each cluster for the above said parameters were taken. The number of swamps in each cluster and the values of the parameteres are presented in the table (5)

Table 5: showing the cluster number and number of swamps in each clusters, mean basal area, mean endemism and mean altitude

Cluster No.	No. of Swamps in each cluster	Mean Basal area	SD	Mean Evergreeness	SD	Mean Endemism	SD	Mean Altitude	SD
1	8	214.21	90.67	93.37	3.63	62.34	6.30	142.5	21.25
2	7	152.85	86.93	79.00	8.01	69.33	8.72	196.14	38.86
3	17	243.94	52.00	94.74	2.33	80.92	5.23	154.00	29.00
4	3	170.11	70.61	99.33	0.58	93.03	3.26	246.00	33.78
5	20	117.60	41.08	94.85	3.17	76.67	6.91	174.35	41.39

The above clustering is represented in the form of cluster dendrogram for better understanding Fig (1).

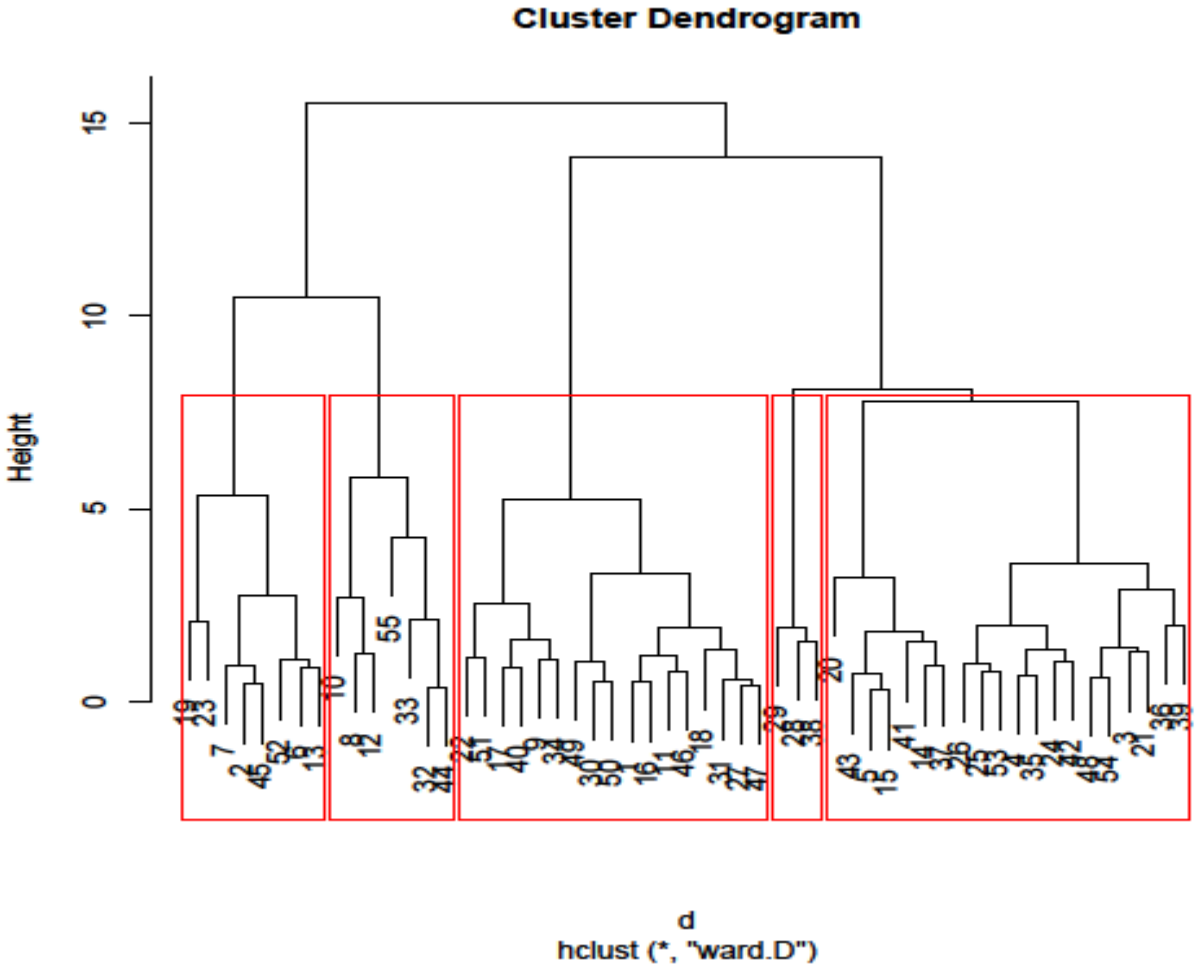


Fig 2: Cluster dendrogram of 55 *Myristica* swamp

To test the statistical significance also the same grouping pattern is followed and parameteres considered are basal area, evergreeness and endemism

One way ANOVA was carried out to compare the groups with respect to basal area, evergreeness and endemism. The results are represented in table (6).

Table 6: showing the results of ANOVA with respect to basal area, evergreeness and endemism between in three groups of swamps

Sl. No.	**Parameters**	**Group 1 (n= 21)**	**Group 2 (n = 20)**	**Group 3 (n= 12)**	**Group 4 (n=2)**	**Statistical Analysis**
1.	Basal area (m^2 ha $^{-1}$)	174.2	97.9	164.5	105.62	NS
2.	Evergreeness %	93.2	93.3	91.8	91.22	NS
3.	Endemism %	78.5	76.5	71.5	70.99	NS

No significant difference was observed in mean basal area, mean evergreeness and mean endemism of the groups.

Interrelationship between of relic species of *Myristica* swamps.

True *Myristica* swamp species have been selected for this study to assess their interrelationship amongst themselves. Analysis of these species viz. *Gymnacranthera canarica*, *Lophopetalum wightianum*, *Mastixia arborea*, *Syzygium travancoricum* and *Vateria indica* for their basal area / hectare is considered.

Out of the above five species, *Vateria indica* is not a true swamp species but it is an endemic and IUCN Critically endangered species and according to the literature and the results of the present study, the species is well represented in *Myristica* swamps. Hence *Vateria indica* is also considered for the analysis.

The basal area per hectare of the five swamp species of all swamps is depicted graphically in the form of Box and Whisker plots (Fig. 2). Being an obligatory swamp species *Gymnacranthera canarica* is present in all the 55 Myristica swamps, *Lophopetalum wightianum* in 47 swamps, *Mastixia arborea* in 18 swamps, *Syzygium travncoricum* in 34 swamps and *Vateria indica* in 24 swamps. The mean basal area of *Gymnacranthera canarica* is highest among 5 species i.e. 221.2 ± 75.5. The lowest value of mean basal area is recorded for *Mastixia arborea* i.e. 5.95 ± 1.3, Table (7).

Table 7: showing basal area of five species, mean and Standard Error

Sl.No.	Species	No. of swamps in which species is present	Mean basal area	Standard Error of Mean (SEM)
1.	*Gymnacranthera canarica* King. (Warb.)	55	221.2	± 75.5
2.	*Syzygium travnacoricum* Gamble	34	93.5	± 53.4
3.	*Mastixia arborea* (Wight) C.B.Clarke	18	5.95	± 1.3
4.	*Lophopetalum wightianum* Arn.	47	91.2	± 73.1
5.	*Vateria indica* L.	24	82.2	± 33.4

The species *Lophopetalum wightianum* which was present in 47 swamps had a mean basal area of 91.2 ± 73.1. *Syzygium travancoricum* which occurred in 34 swamps had a mean basal area of 93.5 ± 53.4.

Distribution of basal area of the five species

The Box and Whisker plots (Fig.3) show that the distribution of basal area of *Gymnacranthera canarica*, *Syzygium travancoricum* and *Mastixia arborea* show a similar pattern namely skewed to the right of the median. With the other two species the distribution is less skewed. With *Gymnacranthera* the basal area is concentrated in the range 0-500, so also with *Vateria* and *Lophopetalum.* The distribution pattern of basal area is different with respect to other two species *Mastixia arborea* and *Syzygium travancoricum*.

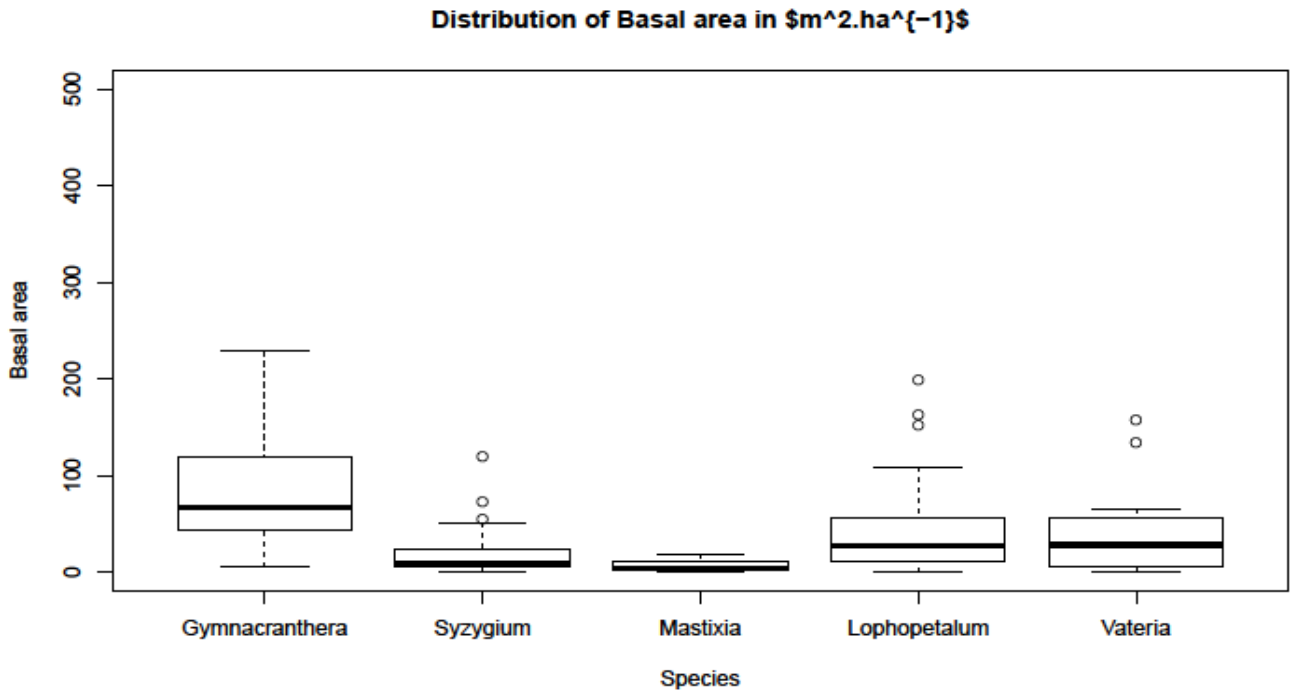


Fig.3: Showing the basal area / hectare of the five species in the *Myristica* swamps

In the box plot the bottom and top lines of the box corresponds the I Quartile (Q_1) and 3 Quartile (Q_3) of the distribution. The top and bottom lines outside the box corresponds to 3 times Q3 and 3 times Q1 respectively.

The points showing outside these lines represent the trees of which the value of basal area is extremely large or extremely small. This holds good for the other species represented in the box plots.

The thick line inside the box corresponds to the median of the observation. Exactly fifty percent of the observations are below this line and the remaining fifty percent are above this line. The larger the width of the box larger the spread of the data. The two lines beyond the box at the top and bottom are corresponding to 1.5 times Q3 and Q1respectively. These are called “hinges”. Any points outside these lines corresponds to extreme values and may be considered as “outliers” *Vateria indica*. The distribution of basal area in *Vateria* is almost symmetric.

The distribution of basal area of all the species is right skewed except. It implies that the spread of the observations greater than median is larger than the observations less than median.

The statistical comparison of the basal areas of the above mentioned five species was carried out using one way ANOVA technique. There was a highly significant difference between the mean basal areas of the 5 species.

Diversity indices, evergreeness and endemism of *Myristica* swamps

In *Myristica* swamps, the Simpsons' index of ranges from 0.3433-0. 9274, Shanon index varies from 1.44 - 3.04.Equitability Index of the ranges from 0.5964 - 0.7567 and N/S Ratio ranges between 23.59-0.7106.

Percentage of Evergreeness of the swamp forest ranges from 62.5 – 100 and Percentage of Endemism from 49 – 96.3.

Structural studies on the Adjoining Forets:

1. Larger adjoining forests- Group1
2. Smaller adjoining areas Group II
3. One hectare Plots Group III

Group I – Larger adjoining forests

Adjoining Forests are dominated by *Lophopetalum wightianum with* IVI 28.066 and second dominant species *Aporosa cardiosperma* with 18.936 IVI and other deciduous components.

Sl.No	**IVI**
Lophopetalum wightianum Arn.	28.066
Aporosa cardiosperma (Gaertn.) Merr.	18.936
Ixora brachiata Roxb.	15.546
Holigarna ferrugenia Marchand	13.197
Archedendron bijeminum	12.253
Terminalia crenulata Roth	12.212
Hopea ponga (Dennst.) Mabb.	12.134
Terminalia paniculata Roth	11.550
Xylia xylocarpa (Roxb.) Taub.	10.416
Knema attenuata Warb.	10.103

Group II – smaller adjoining forests

Hopea parviflora is found to be the dominant species with IVI 38.768 and Lophopetalum wightianum is the second dominant species with IVI 17.064 and dominated by other evergreen species.

Group III - One Hectare Plot

One adjoining hectare plot was plot in Sullia taluk *Myristic*a swamps dominated by *Knema attenuata* and *Myristica malabarica* as dominant species with IVI 43.2685 and 35.0346 respectively.

Family Importance Value (FIV)

Smaller patch of *Myristica* swamps (Quadrats less than 10) accounts the highest value for Myristicaceae family (FIV 100.236) and families like Ancistrocladaceae, Lamiaceae and Bignoniaceae represented by single individuals with FIV 0.1495.

In larger swamps (Quadrats more than 10 and less than 30) Myristicaceae are found to have the highest value (107.151) and second family with highest value is Celastraceae (FIV – 33.4099) and family like Dilleniaceae, Dichapetalaceae and Bignoniaceae are represented by single individual with FIV 0.0606.

Larger swamps Myristicaceae is the dominant family with FIV 85.8211 and least FIV was recorded in the family Lamiaceae 0.0459.

In adjoining forests Celastraceae is the dominant family with FIV 30.7116 and second important family is Phyllanthaceae with FIV 19.0425.

Diversity indices, evergreeness and endemism of Adjoining forests

In Adjoining forests Simpsons' index of ranges from 0.8923 – 09557, Shanon index from 2.86 - 3.4, Equitability Index of the swamp ranges from 0.6234-.8649 and N/S Ratio ranges between 9.04 – 37.39.

Adjoining forests, percentage of Evergreeness ranges between 48 – 94.36 and percentage Endemism varies between 36.12- 64.45.

Structural Parameters of Adjoining forests

Similar parameteres of *Myristica* swamps have been considered for the adjoining forests also.

Pearson's Correlation Matrix of Adjoining forests

Pearson's correlation between basal area & evergreeness, basal area and endemism, basal area and altitude, evergreeness and endemism, evergreeness and altitude and endemism and altitude of adjoining forests indicates the highest correlation of 0.82 between endemism and evergreeness followed by a correlation of 0.43 between basal area and evergreeness .The correlation between basal area and endemism was 0.41. Altitude had low correlation with remaining three factors viz. Basal area (0.25) evergreeness (0.17), endemism (0.05).

Principal component analysis of Basal area, Evergreeness, Endemism and altitude of Adjoining Forests

The adjoining area the first 2 Principal Components accounted for about 80 % of the total variance. The first principal component loading scores indicate that evergreeness and endemism are the important factors where as in the second Principal Component altitude and endemism are having high importance.

Comparison of Basal Area, Evergreeness & Endemism of *Myristica* swamp forests & its Adjoining Forests using t – test

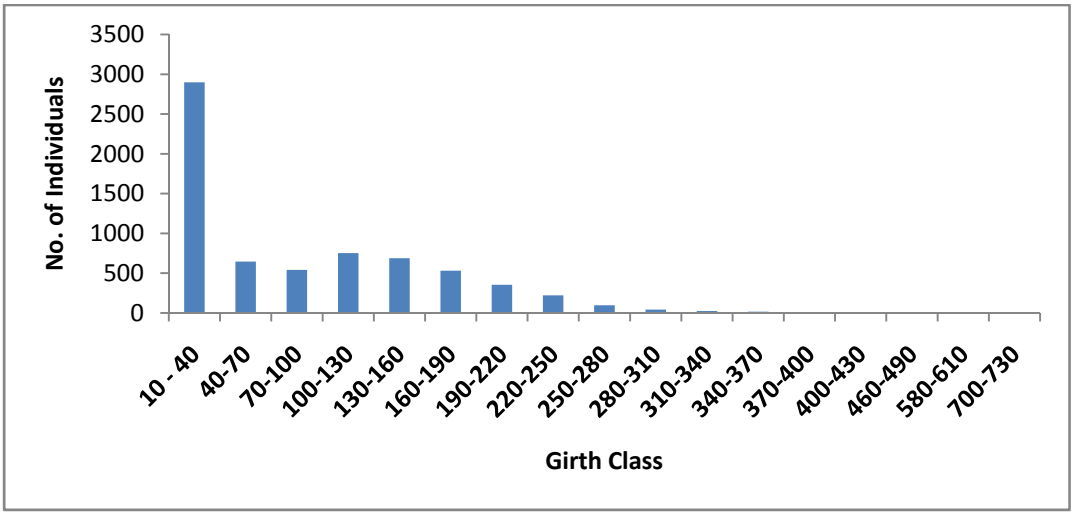
Table 9: Comparison of Basal area, Evergreeness & Endemism of *Myristica* swamps & adjoining forests using t test.

Sl. No.	**Parameters**	***Myristica* Swamp (n=8)**	**Adjoining Forests (n=8)**	**t - test**
		Mean value	**Mean value**	
1.	Basal area(m^2/ha)	167.0	136.3	0.65 (p = 0.52)
2.	Evergreeness (%)	91.6	75.7	2.49 (p = 0.02)
3.	Endemism (%)	68.3	50.3	3.02 (p = 0.009)

There was no significant difference in the mean basal area of the swamp forest and adjoining forest. With respect to percentage of evergreeness there is significant difference between swamps and adjoining forests (p = 0.02) and with respect to percentage endemism there is high significant difference between the swamp and adjoining forests (p = 0.009).

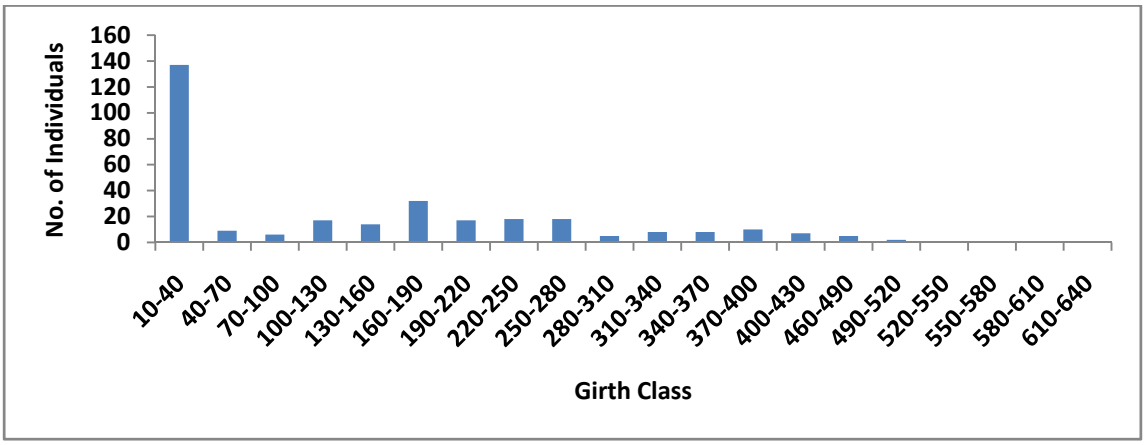
Regeneration status of Important swamp species.

i) *Gymnacranthera canarica* (King.) Warb.



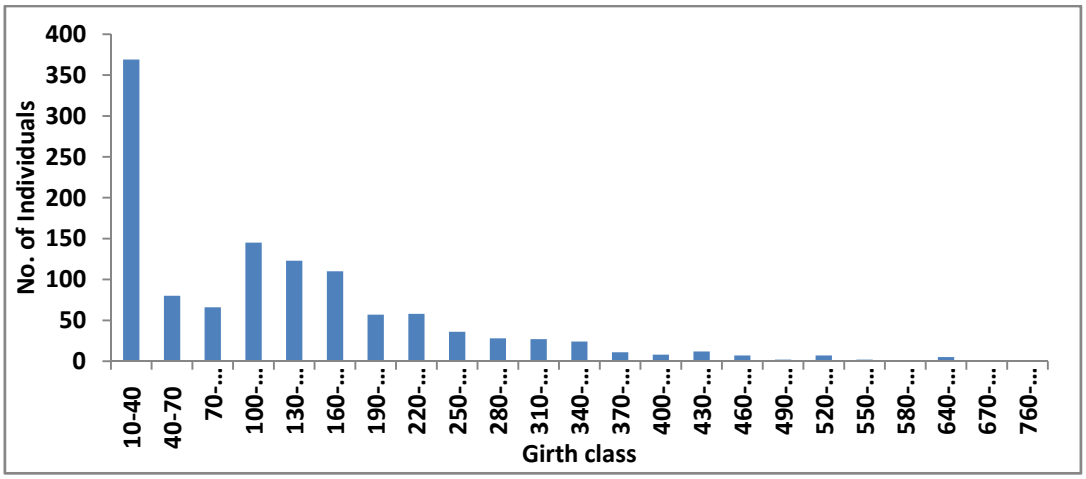
Regeneration is assessed based on the girth - class distribution of individuals. The study resulted in the documentation of 6811 trees and was distributed in 10cms- intervals girth classes. The girth - class distribution indicated a reverse J- shaped curve. Girth classes' upto 200 cm are well represented. The girth class range between 10 cms – 40 cms includes highest number of individuals i.e. 2899 indicating the good regeneration in these forests.

***Syzygium travnacoricum* Gamble**



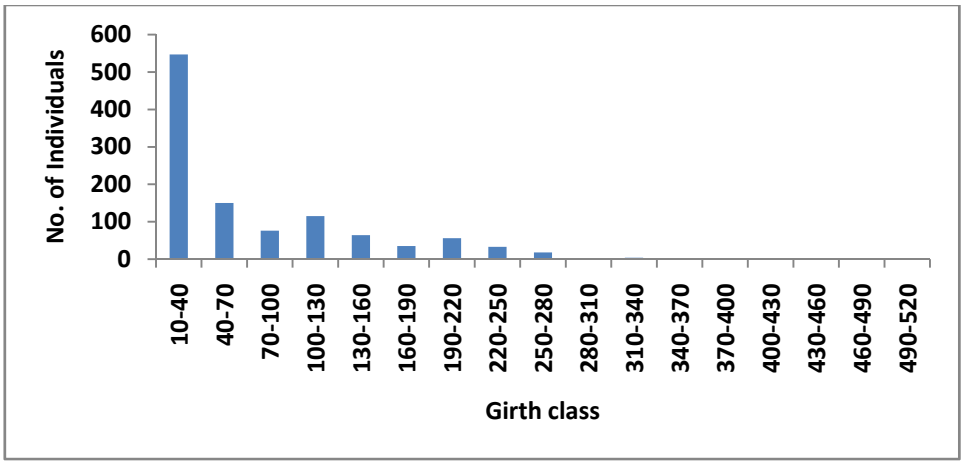
Syzygium travancoricum was represented by 316 trees with the highest girth of 620 cms. The girth class distribution showed a highest number of individuals in (137) 10 cms – 40 cms. Girth class in 160 cms- 190 cms had 37 individuals and girth classes between 520 cms - 640 cms are represented by a single individual.

ii) ***Lophopetalum wightianum* Arn.**



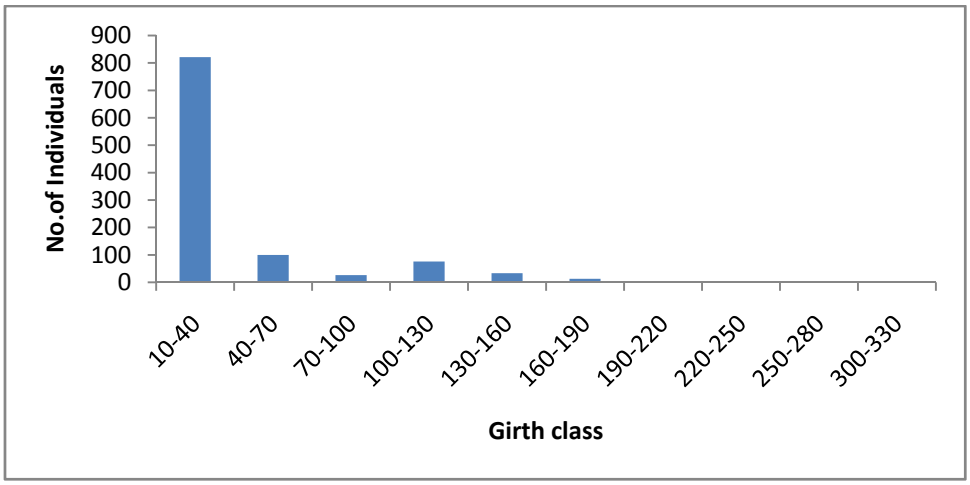
Lophopetalum wightianum was represented by 1180 individuals. The girth class distribution shows a reverse J – shape curve. The highest number of individuals (369) was in the lower girth i.e.10 cms - 40 cms. All girth classes between 40 cms- 440 cms are very well represented and 440 cms – 790 cms girth class represented by 1-3 individuals.

iii) ***Vateria indica* L.**



Girth class distribution of *V. indica* shows that the distribution shows an inverted "J". shaped curve. The 10 cms – 40 cms girth class had 547 individuals numbers followed by pole sized trees and also girth classes 40cms - 220 cms are well represented in the swamps. From girth class 370 cms – 520 cms were represented by single individual. These were trees with huge buttresses.

iv) ***Mastixia arborea***



Girth class distribution of *Mastixia arborea* shows an exact reverse J- Shaped curve with highest number of individuals (821) on the lower girth classes (10cms-40cms). There is a good representation of trees upto 160cm girth class.

ii. Statistical assessment of girth class of individuals

Girth at Breast Height (GBH) readings of all individuals of the species distributed in 55 swamps were taken in to account i.e. *Gymnacranthera canarica* of 6224 individuals, *Lophopetalum wightianum* 1410 individuals, *Mastixia arborea* 1107 stems and *Vateria indica* 1417 stems. These readings are subjected to statistical analysis.

Gymnacranthera canarica is having the highest mean girth of 0.85 and standard error of mean ± 0.91 and the least mean girth was observed i.e. 0.36 and standard error of mean is ± 0.66.

iii. Chi square test

Regeneration study was carried out to check the significance between the total tree number i.e. (GBH ≥ 10 cm) of these 5 species and their respective saplings counted in all the quadrats in shrub layer and herb layer. For this Chi square test was performed.

Based on the Chi square test it is seen that regeneration of swamp species between the tree number and their saplings was found to be highly significant ($p < 0.01$) in all the five species.

Results of Soil Analysis

Selected 26 swampy places i.e. 7 swamps from Group I, 6 swamps from Group II and 11 swamps from Group III and Group IV 2 swamps have been analysed for pH, Nitrogen (N), Phosphorus (P), Potassium (K) and organic carbon (OC).

The soil is silty clay loam, sandy clay medium to weak granular in structure; moist very friable, slightly sticky and non-plastic, fine roots plenty, clear, smooth boundary. Water logged condition in swamp results in high leaching losses of nitrogen. This may be the reason for lower available nitrogen in swamp soils when compared to soils from nearby forest area albeit the available N is far higher compared to crop lands. These microhabitat changes in the swamp may be more important in restricting the species composition. pH, of the soil ranges from 4.03 – 7.52 indicating the acidic nature. Soil is fertile with good amount organic carbon % ranging from 0.6 – 5.73 Kg/ Hectare (Table 10). Majority of the swamps contain sandy clay soil.

Table 10: Range of pH, nitrogen, phosphorous, potassium and organic carbon.

	pH	**N (Kg / Hectare)**	**P (Kg / Hectare)**	**K (Kg / Hectare)**	**OC (Kg / Hectare)**
Surface	4.03 - 6.98	121 – 313.6	2.97-47382	12-140	0.57 - 5.73
0 – 10cm depth	4.73 - 7.08	43.2-301	4.25-110	32-138	0.6 - 4.56
10-20cm depth	4.67 - 7.12	143-301	19.29-30	32-138	0.6 - 2.7
20-30 cm depth	4.79 - 7.52	143.305	0.2-68.62	12-138	0.57- 3.36

4. Germination studies of selected swamp species

i) Seeds Germination studies of *Lophopetalum wightianum* Arn.

Germination of seeds started from the second day of sowing and ended in 6th day in all the replicates, there was no germination beyond 6th day of sowing. Germination was initiated on the second day in many seeds and the percentage germination was 84.37±2.5 %. The seeds sown on the harvested day (0th day). As the day progresses percentage of seeds germinated also decreases. Readings obtained by Cumulative daily total number of seeds germinated (CDTG) also supports this.

Moisture Content

The moisture content of the seeds, immediately after four hours of collection was 15.7 ± 0.3 %. and there was a significant decrease in the moisture content up to 5th day (10.39± 2.1). Then gradual decrease in moisture content was observed up to 20th day and when MC reached 9.21± 0.43(seeds sown 30th day) germination was completely stopped. Moisture content also relates with the cumulative total number of seeds germinated. In the initial days (1-20th) germination is higher. Delayed germination was observed in the seeds sown after 20th days of storage. Germination energy and germination speed also decrease by increasing days of seed storage.

Pearson's Correlation Coefficient between different parameters studied in *Lophopetalum* shows a positive correlation between percentage germination and germination speed; germination percentage and germination energy ($p<0.01$) and also positive correlation is observed between germination speed and germination energy ($p<0.05$).

ii) Seed Germination Studies on *Gymnacranthera canarica* (King.) Warb.

Seeds are single and enclosed in a dark red coloured fleshy aril. Embryos were very small. Hypogeal mode of germination was observed. Germination started at the end of two weeks and extended upto the eight weeks. First leaf occurred after seven weeks. The maximum seed germination recorded was 90%.Initial moisture content of the seed was 38.04 ± 1.7 % which decreased significantly on the 10th day (28.82 ± 1.56 %) and a steady decrease in the moisture content was observed in the subsequent days. On the 50th day moisture content was 16.44 ± 2.57 %. When the MC content reached 14.26 ± 2.3 after 70 days of storage, only a single seed germinated out of 60. Seeds sown on 55th, 60th and 65th day failed to germinate. Moisture of 16.44 ± 2.57%. - 4.26 ± 2.3 % can be considered as the critical moisture level for the germination of these seeds. The Cumulative Daily Total No. of seeds germinated supports this.

The germination speed and germination energy significantly decreased ($p<0.05$) at 50 - 70 days. Significantly high germination speed index was observed on the initial days

SUMMARY AND CONCLUSIONS

- Ecological and floristic studies on the *Myristica* swamps and its adjoining forests have been carried out the present study.
- Total 67 *Myristica* swamps have been identified and a thorough Phytodiversity study and structural study was conducted in 55 *Myristica* swamps.
- Altitude range of these *Myristica* swamp forests lies between 13m – 285m.
- Mapping of *Myristica* swamps of Dakshina Kannada districts was done using the IRS (Indian Resource Sat) satellite data. The image was displayed as virtual stack to get the False Colour Composite (FCC) image in the increasing order of their latitudes.
- The total area of *Myristica* swamps in Dakshina Kannada district was found out through remote sensing is 278.87 Km^2
- Floristic study of *Myristica* swamps resulted in the documentation of 150 species belonging to 114 genera in 51 families (GBH $\geq$ 10 cm).
- Floristic studies on the adjoining forests of *Myristica* swamps resulted in the documentation of 110 species belonging to 89 genera in 42 families
- For stctrual study entire swampy location was sub divided in to three categories viz. Smaller swamps populations (10 and less than 10 quadrats), Medium sized swamps i.e. more than 10 quadrats and larger swamps.
- In all the swamps Myristicaceae family was found to be the dominant family with highest Family Importance Value.
- *Gymnacranthera canarica* an exclusive component of *Myristica* swamps was found to be dominant species in the ecosystem.
- In swamps, Simpsons' index of ranges from 0.3433-0. 9274, Shanon index varies from 1.44 - 3.04.Equitability Index of the ranges from 0.5964 - 0.7567 and N/S Ratio ranging between 23.59-0.7106.
- In Adjoining forests Simpsons' index of ranges from 0.8923 – 09557, Shanon index from 2.86 - 3.4, Equitability Index of the swamp ranges from 0.6234-.8649 and N/S Ratio ranging between 9.04 – 37.39.
- Percentage of Evergreeness of the swamp forest ranges from 62.5 – 100 and Percentage of Endemism from 49 – 96.3
- Adjoining forests Evergreeness ranges from 48 – 94.36 and Endemism was 36.12-64.45.
- Regeneration statuses of swamp species were studied.

- Soil studies were conducted for selected 26 samples for analysing their pH, nitrogen, phosphorus, potassium and organic carbon.
- The above soil parameters were subjected to cluster analysis and principal component analysis.
- Seed germination studies were conducted for *Lophopetalum wightianum* and *Gymnacranthera canarica*
- Hypogeal type of germination was observed in *Lophopetalum wightianum* and germination initiates from the second day of sowing with initial moisture content 15.7 ± 0.3 % and germination was completely stopped when the moisture reached 9.21 ± 0.43 %.
- Seed viability stops within 20- 30 days.
- Germination in *Gymnacranthera canarica* was found to be hypogeal and germination started from 14th day and remained upto 59 days.
- Initial moisture content was 38.04 ± 1.7 %. And when the moisture content reached 14.26 germination was completely stopped.
- Critical moisture level was found to be 16.44 ± 2.57 % - 14.26 ± 2.3%.
- Based on the results of the desiccation study seeds are classified as recalcitrant and can be stored upto two and a half months.

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PUBLICATIONS

1. Seed germination studies on *Lophopetalum wightianum* Arn.- An evergreen species of the Western Ghats, **Keshava Chandra K** , Krishnakumar G and H.S.Shenoy , Published in **International Journal of Plant, Animal and Environmental Science** Vol. 4, Issue 3, 2014.

2. Seed Germination Studies on *Gymnacranthera canarica* (King) Warb. – An Exclusive RED Listed Vulnerable Tree Species of A Critically Endangered *Myristica* Swamp Ecosystem, **Keshava Chandra K** and Krishnakumar G, **Journal of Threatened Taxa** Vol.8, Pp 9009-9013 issue 7, 2016.

PAPERS PRESENTED

1. Keshavachandra K and Krishnakumar G "Structural and floristic studies of a Critically Endangered Ecosystem" at **Capacity Building for Conservation Conference (Asia) at Pune, 2017 University, India.**
2. Keshavachandra K and Krishnakumar G "Structural and Floristic studies on the *Myristica* swamp of Lowland forest in Belthangady Taluk, Dakshina Kannada District of Western Ghats Karnataka – a Critically Endangered Ecosystem" in **103rd Indian Science Congress (ISC), 2016 held at Mysore.**
3. Keshavachandra K and Krishnakumar G, Structural and Floristic studies on the *Myristica* swamp of Molaje in Belthangady Taluk, Dakshina Kannada Districts of Western Ghats Karnataka – an Endangered Ecosystem" in **4th International Science Congress Association (ISCA), 2014** held at Udaipur, Rajasthan.
4. Keshavachandra K, Krishnakumar G & H.S.Shenoy, 'Structural and Floristic studies on the *Myristica* swamp – *an* Endangered Ecosystem' in a UGC Sponsored National Conference on 'World Heritage Tag & Conservation of Biodiversity' **2012 held at St. Philomena College Puttur, Karnataka.**

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